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PRELIMINARY CORRELATION OF LAYERED ROCKS IN THE TATHLITH-KUTAM REGION, KINGDOM OF SAUDI ARABIA, WITH A NOTE ON PREVIOUSLY UNREPORTED MINERAL OCCURRENCES IN THE TATHLITH AREA

by

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THE TATHLITH-KUTAM REGION,

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WITH A NOTE ON

PREVIOUSLY UNREPORTED MINERAL OCCURRENCES

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ABSTRACT

The area of the Tathlith one-degree quadrangle is bordered on the north by layered rocks which tentatively have been placed in the Halaban group, whereas layered rocks on strike to the south of the area, in the Wadi Malahah and Mayza' quadrangles, have been placed in the Jiddah group - an age difference of approximately 100 m.y.

As a result of reconnaissance mapping in the Tathlith area, rocks are divided into groups containing chiefly mafic to intermediate volcanic rocks, felsic volcanic rocks, or sedimentary rocks. These divisions are then carried south into the Kutam area using the descriptions of various authors. The resultant map indicates the possibility that the region between the Tathlith and Kutam areas could once have contained a continuous belt of layered rocks that was later broken up by large batholithic intrusions.

Field observations and laboratory results indicate that some of the layered rocks in the Tathlith and Madha quadrangles may have undergone greater evolution than the rocks in the Wadi Malahah and Mayza' quadrangles. However, it is believed that they all are part of a once continuous sequence.

Several small ancient gold mines and two nickel-bearing gossans are briefly examined.

INTRODUCTION

In 1978 the author was assigned to minerals reconnaissance of the layered rocks in the area of the Tathlith one-degree quadrangle (lat 19-20°N., long 43-44°E.) and spent the periods 9-24 October 1978 and 10-17 February 1979 in reconnaissance mapping by helicopter. This work revealed the presence of several ancient gold mines, two sulfide-bearing gossans, and numerous areas where the rocks contain disseminated pyrite or pyrrhotite.

In addition to minerals reconnaissance, another objective of the study was to map the layered rocks of the Tathlith quadrangle in an attempt to correlate these rocks with layered rocks to the south, namely those in the Markas (18/43 B), Madha (18/43 A), Wadi Malahah (18/43 D), and Mayza' (17/43 B) 30-minute quadrangles. Layered rocks in the area which adjoins the Tathlith quadrangle to the north tentatively have been assigned to the Halaban group, whereas rocks on strike to the south in the Wadi Malahah and Mayza' quadrangles have been assigned to the Jiddah group.

For the past several years the author has worked almost exclusively in minerals reconnaissance within the layered rocks of the Mayza' and Wadi Malahah quadrangles. Consequently, after combining this experience with the present study, an attempt can be made to correlate the northern and southern parts of this rock belt. Geochronology has provided certain age parameters to date, but has not definitely established the ages of the layered rocks in this region.

Previous Work

D. F. Schaffner (1956a, b) of the Directorate General of Mineral Resources (DGMR) reported finding ancient gold mines at Lugatah and Avala as well as asbestos occurrences associated with serpentine in the southern part of the Hamdah quadrangle (19/43 D) (Schaffner, 1964). In 1965 W. C. Overstreet spent several weeks mapping and sampling without air support in the Tathlith one-degree quadrangle. "This work disclosed several deposits of gold, base metals, and industrial rocks, only one of which, the Ash Sha'ib base metal deposit, was subsequently thoroughly evaluated" (Overstreet, 1978). Worl studied the Lugatah and Avala gold deposits in connection with a study of the Jabal Ishmas-Wadi Tathlith fault zone (Worl, 1980 and 1979), and Rooney and Al-Koulak (1979) reported on the asbestos occurrences in the Hamdah quadrangle. Worl and Elsass (1981) mapped in detail the serpentinites located in the southern half of the Hamdah quadrangle and sampled chromium occurrences.

The Riofinex Geological Mission (1978) completed geological, geophysical, and geochemical surveys and drilling in and around the Ash Sha'ib base-metal deposit in the Hamdah quadrangle. A few kilometers north of Ash Sha'ib other deposits have also been mapped and drilled by

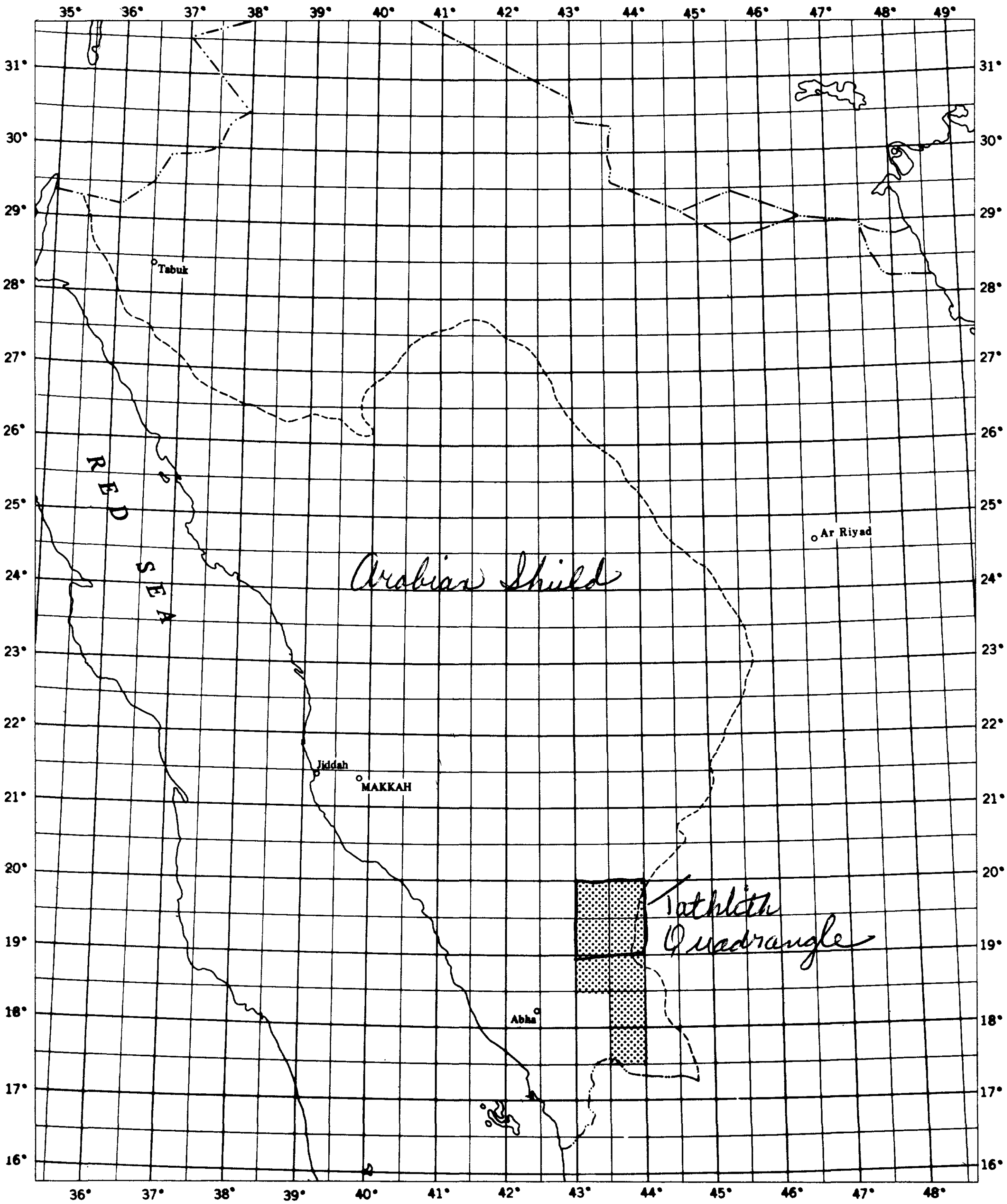

Figure 1.–Index map of western Saudi Arabia, showing location of the Tathlith-Kutam region.

Riofinex. In addition, field work is nearly completed in a program of geological mapping at a scale of 1:50,000 of the Wadi Haraman (19/43 B) and Hamdah (19/43 D) quadrangles. Riofinex (1978) also produced a reconnaissance geological map which includes the Wadi Malahah and Mayza' quadrangles and parts of surrounding quadrangles.

ACKNOWLEDGEMENTS

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GEOLOGY OF THE LAYERED ROCKS IN THE TATHLITH ONE-DEGREE QUADRANGLE

There are no conspicuous compositional differences among the layered rocks within the quadrangle except for marble lenses; units shown on plate 1 reflect only the predominant rock type. Three rock units are recognized, based on the predominance of either basic to intermediate volcanic rocks, felsic volcanic rocks, or sedimentary rocks. The majority of the sedimentary rocks are immature, poorly sorted, and only locally well layered. The majority of the volcanic rocks are tuffs; volcanic flows are only locally in abundance.

Stratigraphy of the Tathlith one-degree quadrangle

No evidence for tops and bottoms of stratigraphic sections was found during mapping and because of folding and faulting no estimate of stratigraphic thicknesses can be given. Schmidt (in press), in mapping of the Jabal al Qarah quadrangle (20/43 C) located to the north of the Al Hassir quadrangle (19/43 A), roughly estimates the thickness of basaltic and andesitic rocks at 500 m, andesitic rocks at 3000 m, and volcaniclastic rocks at a minimum of several thousand meters.

Al Hassir quadrangle, sheet 19/43 A

Layered rocks are found almost exclusively in the eastern part of the quadrangle area (pl. 1). They consist primarily of interbedded tuffs and volcanic-derived sedimentary rocks, with minor amounts of flow rocks. They include conglomerate , volcanic wacke , water-laid tuff , ash flow tuff , argillite , black shale , calcareous mudstones, and thin quartzofeldspathic sedimentary rock layers, pyritized chert beds, and marble layers. Thin basalt and andesite porphyry flows are interbedded with the sedimentary rocks and tuffs and comprise only a minor part of the stratigraphic column. The layered rocks are dark grayish green and require close inspection for identification. Water-laid felsic to intermediate tuffs predominate, but the origin of many of the finer grained rocks is difficult to determine because of the masking effects of thermal metamorphism, especially evident near contacts with plutonic rocks

Folding, faulting, and metamorphic effects all contribute to making the measurement of a complete stratigraphic section difficult, if not impossible. Most layering is vertical or near vertical. The stratigraphic sequence is as follows, going from west to east: subvolcanic microdiorite and diorite containing lenticular, brown to gray, non-layered marble xenoliths. These marble lenses normally occur as boudins in shear zones. One large xenolith within the microdiorite contains argillite and black shale as well as marble lenses. East of this zone a north-trending belt of layered rocks extends almost the complete length of the quadrangle. These rocks range in composition from tuffs and volcanic sedimentary rocks, derived mostly from intermediate rocks, to felsic tuffs with minor flows which border the eastern edge of the quadrangle.

Wadi Haraman quadrangle, sheet 19/43 B

Layered rocks in this quadrangle area are part of a continuous series extending from the Al Hassir quadrangle to the west (pl. 1). Metasedimentary rocks predominate and include conglomerates, graywackes, argillite , calcareous argillite , impure quartzite , and marble . Tuffaceous rocks, including felsic quartz crystal-and lapilli tuff and tuff of intermediate composition, are interlayered with the sedimentary rocks, as are thin layers of basaltic and andesitic flows. Felsic volcanic rocks, many of which occur as flows, are concentrated along the northwestern edge of the quadrangle. These are fine grained and massive and locally contain orthoclase phenocrysts.

The rocks are dark grayish green and weather from hackley textures to semirounded forms; cleavage and schistosity are not pronounced. In many outcrops well-defined layering may be observed. Near contacts with plutons, the layered rocks have been thermally metamorphosed to biotite and hornblende schists and hornfelsic rocks.

Away from plutonic contacts the layered rocks have undergone moderate regional metamorphism at the lower greenschist facies.

Duther as Salam quadrangle, sheet 19/43 C

The rocks in this quadrangle area are mostly volcanic in origin and are undoubtedly the southern continuation of the volcanic rocks of the Al Hassir quadrangle (pl. 1). On the western edge of the layered-rock outcrops, rhyolitic to dacitic flow rocks predominate. These are fine grained, dense, and dark gray, and locally host potassium feldspar. A sharp peak formed by a rhyolite plug is a landmark within this zone (pl. 1). These felsic volcanic rocks weather gray to dark gray, are weakly foliated and massive, and are not layered. Volcanic rocks of intermediate composition are in contact with the felsic volcanic rocks to the east and south. They consist principally of andesitic flows but also include basaltic and rhyolitic flows. Tuffaceous rocks occur in minor amounts within this zone. The andesites are dark gray green, massive, locally vesicular, and non-layered. Close examination is required to identify all rocks within this area because of outward similarities in the outcrop appearance of most of the rock types. Large marble lenses are found at the contacts of the andesites with both intrusive rocks to the west and felsic volcanic rocks to the east.

The felsic volcanic rock series on the eastern edge contains more pyroclastic rocks than that to the west; it includes interbedded argillite , calcareous argillite , quartz crystal tuff , basalt flows containing long, slender plagioclase crystals, and andesite flows. A series of rhyolite dikes cuts the felsic volcanic rock series on its eastern edge.

The Nabatiyah (Schmidt, in press) or Jabal Ishmas-Wadi Tathlith (Worl, 1980) fault zone passes in a northerly direction along the eastern edge of the quadrangle area. A great volume of mafic to ultramafic rock has been intruded along the fault and serpentinization of that rock has taken place within a zone approximately 15 km long. The serpentine is dark yellow, green to black, and contains isolated, irregular zones altered to buff-brown dolomite. Basalt flows in contact with the serpentine on the east are also weakly serpentinized.

Hamdah quadrangle, sheet 19/43 D

In most places within this quadrangle area, mapping the layered rocks is difficult because of the masking effects of thermal metamorphism. Granitization, migmatization, and amphibolitization effects are prevalent within the west-central part of the quadrangle area and, in some places, completely mask original rock characteristics. Nevertheless, layered rocks in the quadrangle are believed to be the southern extension of the same types of rocks found in the Wadi Haraman quadrangle (pl. 1). They grade from primarily volcanic in the western part of the quadrangle area to chiefly sedimentary in the center.

The felsic rocks on the western edge of the quadrangle area are primarily massive quartz crystal tuffs interbedded with siliceous, flinty, layered rocks that are probably metasedimentary rocks and roughly layered andesites. Rocks of andesitic composition abound in the quadrangle and they very much resemble those types of rocks described in adjoining quadrangles. They are massive, ordinarily nonlayered, and appear in sections several hundreds of meters thick. They are interbedded with both felsic volcanic rocks and sedimentary rocks. The sedimentary rocks include impure quartzite , pebble conglomerate , well-bedded hornfelsic argillite , and pyritized chert beds. Calcareous rocks are not as prevalent here as in the Wadi Haraman quadrangle area to the north, but dark-gray to black marbles are distinctive and typical of the general area. According to Noel Sheppy (written commun.), graphitic rocks are present locally within the quadrangle area and grade laterally from nearly pure graphitic schists to felsic volcanic rocks containing graphitic layers. In the southeastern part of the quadrangle area there is a wide zone of broadly flexured, thinly bedded argillites that have been domed by a felsic intrusive body. These rocks are slightly amphibolitized and primary features are well retained. They display clean quartzite layers, and layering within the argillite varies from light to dark gray. They weather to flaggy, blocky forms, are gray brown, and appear to be more mature than any other sedimentary section mapped in the area.

The serpentinites which crop out in the southern part of the quadrangle area have been mapped in detail by Worl (1980) and will not be discussed here. Mafic to ultramafic plutonic rocks were mapped where encountered and are shown on plate 1. The objective of this work was to study these rocks for possible indications of serpentinization and accompanying sulfide mineralization.

PRELIMINARY CORRELATION OF LAYERED ROCKS IN THE TATHLITH-KUTAM REGION

A belt of metavolcanic and metasedimentary rocks is discontinuous throughout the area between Tathlith and Kutam (pl. 1), a distance of more than 275 km. These layered rocks are part of a much greater belt which extends far north of Tathlith and south of Kutam. The layered rocks are interrupted by large batholitic intrusions including the Wadi Tarib batholith and the Malahah dome and large areas of felsic intrusions in the Markas and Tathlith quadrangle areas. Most of the rocks are directly or indirectly of volcanic derivation and are typical of layered rocks produced in a mobile crustal environment such as an island arc. The belt averages 50 km in width and is bordered by felsic plutonic rocks on both its eastern and western sides.

Mapping in the Tathlith region disclosed areas of layered rocks which could be grouped into three broad categories based on the predominance of rocks which were either of mafic to intermediate volcanic, felsic volcanic, or sedimentary origin. Using descriptions supplied by various mappers of the remaining quadrangles in the belt, and applying the author's observations, these categories were then applied to layered rocks extending south into the Markas, Madha, Wadi Malahah, and Mayza' quadrangles (pl. 1).

Correlation of layered rocks of chiefly mafic to intermediate volcanic origin

The considerable thickness of andesitic volcanics found in the Tathlith one-degree quadrangle area is by no means unique for these rocks which are found in abundance throughout the Tathlith-Kutam belt.

In the Madha quadrangle area a narrow north-trending belt of layered rocks composed of interlayered metavolcanic and metasedimentary rocks extends along the eastern edge of the quadrangle (pl. 1) (Simmons, 1980). Simmons describes these rocks as being chiefly intermediate in composition including andesite , dacite , latite , and quartz latite . They are predominantly crystal tuffs interlayered with thin basalt flows. Metasedimentary rocks include marble , conglomerate , quartzite , and graywacke .

These rocks are undoubtedly the southern continuation of the layered rocks found in the Duthur as Salam quadrangle. Field examination by the author revealed that they have the same general composition as rocks to the north, being moderately to slightly schistose, massive, and dark gray green.

Rocks of principally andesitic composition pass south from the Hamdah quadrangle into the Markas quadrangle. Worl (1981; pl. 1), in mapping of the Jabal al Hajrah 7-1/2 minute quadrangle, states: "layered rocks in the Jabal al Hajrah quadrangle are metamorphosed volcanic and volcaniclastic rocks of mafic to intermediate composition and related metasedimentary rocks." He divides these rocks into four informal units: quartz-biotite schist, hornblende schist, carbonaceous schist, and chlorite-epidote schist. The hornblende schist is thought by Worl to have derived "largely from andesitic pyroclastic rocks and graywackes and subordinately massive andesitic flow rocks." Worl and Elsass (1980) and Helaby and Worl (1981) (pl. 1), in mapping serpentinites and gold deposits in the Hamdah area, retain the same nomenclature for the layered rocks and divide them on the basis of their position in respect to the serpentinite sheets, that is, whether they overlie or underlie the serpentinite.

Warden (unpub. data) mapped the Markas quadrangle in 1969 and describes rocks in the northern part of the quadrangle as "being composed chiefly of mafic metavolcanics including agglomerate and pillow basalt interlayered with amphibolitized metasediments of argillaceous origin and locally with graphitic slate." In places, "basaltic and andesitic rocks are interbedded with graywacke and calcareous mudstone."

South of Al Hajrah, layered rocks are largely cut off by faulting and by large felsic plutons; they reappear in the southern part of the quadrangle where Warden divides them into four informal categories: feldspathic psammites including meta-arkoses, biotite amphibolite schist, biotite schist, and rocks of mainly sedimentary origin. Migmatization and amphibolitization have almost obliterated original textures; consequently it is not known if mafic to intermediate volcanic rocks were originally part of the stratigraphic section in this area.

W. R. Greenwood (1980a) mapped the Wadi Malahah quadrangle. Though layered rocks appear to pass from the Markas quadrangle into the Wadi Malahah quadrangle, they are cut off in the north by intrusive rocks of the Malahah dome (pl. 1). Mapping by Warden and Greenwood does not correlate where the two quadrangles adjoin, since Greenwood assigns all of the rocks bordering the northern edge of the Malahah quadrangle to the Malahah dome plutonic complex. He shows a large xenolithic remnant of mafic to intermediate volcanic rocks near the northern border, and a few kilometers south of this, where layered rocks are undisturbed by plutons, great thicknesses of these rocks continue south into the Mayza' quadrangle.

Greenwood describes the mafic to intermediate rocks in the Wadi Malahah quadrangle as including green to dark gray-green basaltic to dacitic flows and volcanic breccias, cinder tuffs, and massive to poorly bedded green crystal and crystal-lithic tuffs of similar composition. The unit contains subordinate amounts of poorly to well-bedded, green to gray, volcaniclastic rocks ranging from cobble conglomerates to phyllites, and locally contains minor amounts of green chert and a few thin reddish-brown to dark-gray marble beds.

The author has worked extensively within confined areas of the Wadi Malahah quadrangle, essentially in the Dhahar region (pl. 1) (Smith, 198[illegible]). Within this zone Greenwood (1980a) mapped mafic volcanic rocks of the Wassat formation as being complexly folded and faulted and interlayered with quartz porphyry sills (not shown on plate 1). His description of the rocks of the Wassat formation closely matches the findings of the author.

The Riofinex Geological Mission (1978) published a report with maps, which includes detailed stratigraphy of the metavolcanic and metasedimentary rocks in the Wadi Malahah and Mayza' quadrangles and parts of the Wadi Wassat and Wadi Hawbanah quadrangles. Rock-type divisions are somewhat different from those of Greenwood (1980a, b) and Anderson (1978); Riofinex divides the mafic rocks into two groups: MV_1- lower mafic volcanic unit, basaltic to andesitic flows, breccias and tuffs with volcaniclastic conglomerate, sandstone (graywacke), argillite , black shale , chert , and marble ; and MV_2 - upper mafic volcanic unit, metabasaltic to meta-andesitic flows, breccias and tuff , with volcanic sandstone (graywacke) and argillite . These rocks were placed in the stratigraphic column in reference to what is termed the middle stratigraphic unit, which consists mainly of volcaniclastic sedimentary rocks.

Anderson (1978) mapped the Mayza' quadrangle (pl. 1) and his description of the mafic to intermediate volcanic rocks that pass from the Wadi Malahah into the Mayza' quadrangle area is as follows: massive to schistose andesites and basalt lavas and flow breccias, amygdaloidal locally; sparse pillow structure with minor interbedded sedimentary rocks. Much of the Mayza' quadrangle is underlain by these rock types, and other formations, as mapped by Anderson, contain interbedded mafic to intermediate volcanic flows and tuffs.

The author has worked in the southwestern part of the Mayza' quadrangle in an area which includes the Kutam and Farah Garan ancient mines (pl. 1); he agrees that much of the mafic to intermediate volcanic rock section consists of massive to schistose andesites, basalt lavas, and flow breccias. However, large areas were found to be underlain by tuffaceous rocks of the same general composition.

Correlation of layered rocks of chiefly felsic volcanic origin

Felsic volcanic rocks in the Tathlith one-degree quadrangle area are mostly volcaniclastic in origin and generally are massive, flinty, and gray green. Most bear quartz crystals ranging from pin-point size to 1/2 cm in diameter. Some of the quartz crystals are blue tinted and subhedral. Pyroclastic breccias are common, and rhyolites bearing orthoclase phenocrysts are found locally. Further south, in the Madha quadrangle, Simmons (1980) reports the presence of latites in the layered rocks that continue south from the Duthur as Salam quadrangle.

Both Warden (unpub. data) and Worl (1981) report quartz crystal tuffs in the northern part of the Markas quadrangle, and Warden mapped flow-banded acid lavas containing feldspar phenocrysts and fragments and blue-tinted quartz crystals within the same area (not shown on plate 1).

In the Wadi Malahah and Mayza' quadrangles, two fields of thought exist concerning the origin of vast areas of unlayered, gray-green, chloritized, sericitized, and locally silicified rocks that bear blue-tinted subhedral quartz crystals. Greenwood (1980a) and Anderson (1978) believe these rocks to be of intrusive origin, whereas Thor Kiilsgaard (personal communication), David Bent of Noranda Exploration Company (personal communication), members of the Riofinex Geological Mission (1978), and the author (Smith + others, 1978, Smith, 1979, 1980) believe these rocks are chiefly volcaniclastic in origin. In both the Kutam area of the Mayza' quadrangle and the Dhahar area of the Wadi Malahah quadrangle, the author found fossil-weathered surfaces containing rubble, layers of pyroclastic breccias, layers of carbonaceous rocks, and layers containing pumice fragments. Indeed, many of the quartz crystal tuffs in the Tathlith one-degree quadrangle area appear very similar in composition and texture to those of the Malahah and Mayza' quadrangles.

The Riofinex Geological Mission (1978) reconnaissance geological map of southeast Asir (scale 1:100,000) shows two rhyolite formations covering an area several square kilometers in size. One is located in the area of the Wadi Malahah quadrangle at lat 18°15'N., long 43°59'E., and the other is located in the area along the western edge of the Wadi Wassat quadrangle (not shown on plate 1). No details concerning these rocks are given, and Greenwood's maps (1980a, b) shows no rhyolite in these areas of the Wadi

Malahah and Wadi Wassat quadrangles. Potassium feldspar-bearing volcanic rocks were not mapped by any of the workers in the Mayza' quadrangle.

Correlation of layered rocks of chiefly sedimentary origin

Metasedimentary rocks of the Tathlith one-degree quadrangle area pass south into the area of Markas quadrangle (pl. 1) where Worl (1981) describes the occurrence of pyritic carbonaceous schists with an extremely fine-grained siliceous groundmass. The carbonaceous rocks are interbedded and integradational with phyllite, phyllitic quartzite, and black marble. Warden (unpub. data) also mapped metasedimentary units in the northern part of the quadrangle. They are interbedded with volcanic units and are not shown on plate 1. They include graywacke , argillite , impure quartzite , and calcareous mudstone . The rocks are similar to metasedimentary rocks mapped to the north, being gray green, in places flaggy, and showing primary layering.

Warden also mapped layered rocks in the southern part of the quadrangle and divided the rocks into four categories: feldspathic psammites and meta-arkoses, biotite amphibolite schists, biotite schists, and rocks of mainly sedimentary origin.

Stratigraphic sequences were not developed by either Warden or Worl; however Worl developed sequences which underlie or overlie serpentine rocks.

In the Wadi Malahah quadrangle, Greenwood (1980a) describes the metasedimentary rocks as follows: Qatan Formation-graphitic metasedimentary rocks; gray to dark gray, weathering to light brown; conglomerate to phyllite with minor interbedded red-brown to dark-gray marble ; predominantly fine sandstones to phyllites. Clasts include quartz porphyry, plagioclase porphyry, trachytic-textured felsite, graphitic phyllites, and marble . There are also green to gray metasedimentary rocks, green to gray conglomerates to phyllites, and minor interbedded red-brown to gray marbles. Clasts include plagioclase porphyries, quartz porphyries, and gray phyllites. The unit contains graded beds and penecontemporaneous deformation structures; it also contains subordinate amounts of amygdaloidal porphyritic andesite, andesite hyaloclastic breccias, and volcanic conglomerates. A thick subunit of pebble conglomerate is centered around Shasrah (pl. 1).

The Riofinex Geological Mission (1978) categorizes the metasedimentary-metavolcanic complex of the Wadi Malahah and Mayza' quadrangles somewhat differently than Greenwood (1980a) and Anderson (1978). Riofinex describes the complex as a volcaniclastic sedimentary association: green to gray-green andesitic to rhyolitic bedded tuffs, volcaniclastic conglomerates and sandstones (graywacke), argillites, siliceous shales, cherts, marbles, and black graphitic shales; locally mafic to felsic flows and breccias. These rocks overlie a black shale association: black, locally graphitic, pyritic to hematitic shales, siliceous (felsic) tuffs, tuffaceous cherts, volcaniclastic breccias and conglomerates, pebbly argillites, black marbles, and gray-green argillites.

The author mapped in detail a small gold prospect at Shasrah (Smith 198[illegible]) and made a geological traverse from there to a point east of the Dhahar ancient workings (pl. 1). At Shasrah, the rocks are moderately well sorted pebble conglomerates containing phyllite, marble, and quartz porphyry. Going east the rocks change to black, carbonaceous, pyritiferous phyllites with narrow beds of light-gray sandstone. The thick sequence of pyritiferous, carbonacaeous rocks continues and becomes progressively more massive and siliceous to a point 11 km east of Dhahar where it consists of lighter gray fine-grained phyllites interbedded with graywackes. These metasedimentary rocks continue for another kilometer to the west where they come in contact with the metabasalts of the Wassat formation.

Metasedimentary rocks continue south into the Mayza' quadrangle where Anderson (1978) mapped units containing bedded cherts, chert pebble conglomerates, slate, graphitic schists, and thick-bedded to massive mudstone-pebble conglomerates. In mapping in the Kutam-Farah Garan region the author (Smith, 1979; Smith and others, 1978) mapped graphitic schists, graywackes, cherty horizons, argillites, calcareous mudstones, and large areas of light-brown dolomite. The sedimentary rocks are interbedded with volcanic rocks ranging from mafic to felsic in composition.

In a discussion of the metasedimentary units of the Tathlith-Kutam belt, it is pertinent to mention that Simmons (1980), in his description of the mixed metavolcanic and metasedimentary unit (MV_4) of the Madha quadrangle, states: "A prominent line of conglomerate, more than 1 km long is found along Wadi 'Areen, near its confluence to Wadi Miflek (N18°53'46"; E43°24'26"). This conglomerate contains abundant, well-rounded pebbles and small cobbles imbedded in a matrix of greenstone. The pebbles and cobbles are mostly very fine grained greenstone; many are silicified and contain disseminated pyrite; a few of the pebbles are gneissic granodiorite." According to Simmons, MV_4 lies nonconformably on granodiorite gneiss and is intruded by diorite, granodiorite, quartz diorite, alaskite, and granite.

Stoeser and Greenwood (personal communication) have examined the MV_4 conglomerate and find that the rock is composed chiefly of mafic volcanic rocks, but also contains fragments of quartz diorite and tonalite. From this observation they propose a penecontemporaneous age for segments of the Wadi Tarib batholith and the MV_4 formation.

DISCUSSION

The belt of layered rocks under discussion is interpreted by various workers as being of different ages in the north and south. Schmidt (in press) gives a tentative age of 780 to 740 m.y. for the oldest layered rocks of the Jabal al Qarah quadrangle, the northernmost quadrangle treated in this discussion. He tentatively defines the rocks as being part of the Halaban group, stating that the rock ages are assigned on the basis of lithology and rubidium-strontium dates of considerable uncertainty. Overstreet (1978), on the other hand, makes a vastly different interpretation concerning ages of the layered rocks of the Tathlith one-degree quadrangle area. He assigns rocks in various parts of the quadrangle to units having as great a divergency in age as the Hali group, Khamis Mushayt gneiss, Baish group, Bahah group, Jiddah group, Halaban group, and Murdama group. Two of the workers to the south of the Tathlith one-degree quadrangle make no committment as to the age of layered rocks. These include Simmons (1980) of the Madha quadrangle and Worl (1981) of the Markas quadrangle. Warden (unpub. data) comments that dates of 620 to 580 m.y., obtained by Aldrich and others (1978), are upper age limits coincident with the Pan African event, and that no data on absolute age of layered rocks is available. He then tentatively assigns the layered rocks ages somewhat younger than 1000 m.y. Two dates obtained by later workers (Cooper and others, 1979) using the zircon method suggest that the layered rocks in the Hamdah region (pl. 1) can be no younger than 660-700 m.y. or 664 ± 12 m.y., although the first date given is not a good measurement. Further south, in the Wadi Malahah and Mayza' quadrangles Greenwood and others (1980) define the layered rocks of those quadrangles as belonging to the Jiddah group with an age of at least 890 m.y., using rubidium-strontium (Rb-Sr) age dating. Subsequent work by Fleck and others (1980) assigns layered rocks of the Wadi Malahah quadrangle ages of at least 684 ± 43 m.y., as measured by Rb-Sr method. Great uncertainty exists as to the authenticity of other Rb-Sr dates from samples in the Wadi Wassat and southwestern part of the Wadi Malahah quadrangles where ages of 843±273 m.y. and 846±82 m.y. were obtained (Fleck and others, 1980). Two zircon dates from the Wadi Tarib batholith (Cooper and others, 1979), in the Wadi Tarib quadrangle, give ages of 714±28 m.y. and 660±7 m.y. and one potassium-argon date (Aldrich and others, 1978) in the Wadi Tarib batholith, in the western part of the Wadi Malahah quadrangle, gives a date of 686±14 m.y.

Greenwood and others (1980) studied the geochemistry of Jiddah and Halaban group rocks and state that the Na_2O/K_2O ratios found in rocks of both the groups suggest an affinity with island-arc calc-alkaline rocks despite widespread potassium metasomatism. Both groups were found to be higher in potassium content than normal tholeiitic or calc-alkaline island arc rocks. The silica content of the Halaban group was found to be 68 percent as opposed to 58 percent for Jiddah group rocks. To Greenwood and others (1980) this reflects a tendency toward differentiation trends suggesting a younger age for Halaban group rocks. Upon further comparison of chemistry, Greenwood and others state that the Arabian craton was formed according to the configuration of an island arc with volcanic rocks becoming progressively younger to the northeast. Three overlapping belts, each with distinct chemistry, include (1) an apparently early belt of tholeiitic basalts and basaltic andesites that show strong iron fractionation and low K/Na ratios (Baish group), (2) a medium-age (?) belt of predominantly tholeiitic basalts, andesites and dacites that show moderate iron fractionation (Jiddah group), and (3) a younger belt of calc-alkalic and tholeiitic andesites that show no iron fractionation and have high K/Na ratios (Halaban group). The authors diagram an island arc with subduction zone sloping to the east and give four time periods from the formation of the island arc to the development of an Arabian neocraton. These time periods are Baish, 1160 m.y.; Jiddah, 890 m.y.; Halaban; and Shammar (no times given).

Schmidt and others (1978), in their discussion of the crustal history of the Arabian Shield, diagram a west-dipping subduction zone and propose that accretion of the Arabian craton progressed to the east. Their models incorporate geology of the Jabal al Qarah quadrangle and the time frame for formation of Halaban group rocks is designated by radiometric age dating in that area.

Hadley and Schmidt (1979) discuss the evolution of the sedimentary rocks and basins of the Arabian Shield and on the basis of composition and texture propose three depositional phases: Phase I (the oldest) includes Baish, Bahah, and Jiddah groups and consists of an immature assemblage dominated by fine-grained metagraywackes, graphitic schists, cherts, marbles, and subordinate amounts of polymictic conglomerates and metasiltstones. The clastic rocks of this phase are composed solely of volcanic material and do not contain plutonic or sialic detritus. Phase II includes metasandstones and abundant marbles, which are stromatolitic in places. The Ablah, Halaban, and Murdama groups are typical of Phase II, where potassium-feldspar detrital fragments are common in the Halaban and Murdama groups. Sedimentary rocks of Phase III (youngest) are fine-to coarse-grained terrigenous clastic rocks, boulder conglomerates, and stromatolitic limestones and dolomites. The Shammar and Jubaylah groups form Phase III. Hadley and Schmidt (1979) emphasize the evolutionary character of sedimentary basins progressing from west to east in the Arabian Shield.

Lead isotope dating by Stacey and others (1980) includes a sulfide sample from the Kutam deposit where an age of 600 m.y. was determined. Rye and others (in press) examined Kutam sulfides in a sulfur isotope study and propose a volcanigenic origin for the deposit. This information suggests that the deposit was formed contemporaneously or penecontemporaneously with the enclosing volcanic rocks. A calibration study on lead in potassium feldspar from the Wadi Tarib batholith was compared to zircon age dating results from the same area (Cooper and others, 1979), and results 30 to 50 m.y. younger were obtained for the lead isotope dating. Cooper and others also state that low, near-mantle values of Pb^{207}/Pb^{204} exhibited by ore deposits in the main part of the Arabian Shield indicate that the craton developed from an oceanic crustal environment. The authors are not pleased with the age of 600 m.y. provided by lead isotope dating for the Kutam deposit since they believe the enclosing rocks are much older. They then qualify the date by stating that the deposit has been severely sheared and remobilized so that base-metal sulfides occur at fault junctions, and that the lead in the deposit may have been introduced during metamorphism about 600 m.y. ago.

CONCLUSIONS

Much of the evidence gathered by previous workers and the author suggests that the Tathlith-Kutam belt of layered rocks is composed of volcanic rocks and volcanic-derived immature sedimentary rocks typical of an island arc environment, and that the north-trending layering of the rocks, although greatly modified by folding and faulting, is a remnant of the original primitive structure formed by accretion to a neocraton. Progressively younger rocks found in easterly and northeasterly directions indicate that craton accretion progressed in those directions. Similarity of the geology of the layered rocks throughout the Tathlith-Kutam belt becomes apparent by applying the classification as shown in plate 1. Although the categories applied are very general and subject to reclassification by more thorough study, they serve to demonstrate the possibility that at some time during the geologic history of the Arabian craton the layered rocks formed a continuous belt from Kutam to the Tathlith region.

Major Najd-type faulting and displacement is not a prominant feature within the belt, although rocks in the Markas quadrangle area are faulted along a west-northwest trend. Studies of the western extension of the fault zone in the Duthur as Salam and Madha quadrangles indicate a continuous sequence along strike with no major breaks detected.

Contrasting evidence that suggests the rocks in the southern and northern ends of the belt originated at different times includes the following.

1. Geochemical studies by Greenwood and others (1980) shows the silica content of the Halaban group to be 68 percent as opposed to 58 percent for the Jiddah group. The Halaban group rocks have higher K/Na ratios and have undergone less iron fractionation than those of the Jiddah group. The Halaban group rocks are calc-alkalic and tholeiitic andesites whereas Jiddah group rocks are predominantly tholeiitic mantle-derived (?) basalts, andesites, and dacites. Accordingly, mapping of the Tathlith quadrangle by the author disclosed the presence of rhyolitic and latitic flows containing potassium feldspar phenocrysts in addition to clastic potassium feldspars in the metasedimentary rocks. The potassium feldspars, however, were found only locally and this observation agrees with that of Schmidt (in prep.), who describes potassium feldspar-bearing volcanic and metasedimentary rocks as being a very minor part of the stratigraphic section. Generally speaking, the layered rocks are very siliceous. These rocks make up a very minor part of the section in the southern part of the belt but rhyolites were mapped by Warden (unpub. data) in the northern part of the Markas quadrangle area and by the Riofinex Geological Mission (1978) in both the Wadi Malahah and Wadi Wassat quadrangles.

In consideration of the above findings, it should be recognized that samples of Halaban group rocks analyzed for these studies were very likely not taken from the Tathlith-Kutam belt of rocks. Consequently, results of the studies should be applied only very generally.

2. In some places within the belt metasedimentary rocks appear to be more mature. South and west of the layered gabbro in the Hamdah quadrangle area, domed sedimentary rocks include finely layered, clean quartzites interlayered with thinly layered argillites of contrasting colors. The sedimentary rocks are well sorted and layering is persistent along strike. They appear to be of terrigenous origin. Noel Sheppy of the Riofinex Geological Mission (personal communication) believes that these particular sedimentary rocks and others of the same general appearance found 15 km northeast of Ash Sha'ib may indeed be younger than and resting unconformably on the older metasedimentary rocks.

3. The general appearance of layered rocks in the Tathlith area contrasts with that of the layered rocks in the Kutam region. In the Tathlith area nearly all rocks are dark greenish gray to black and markedly less schistose than the multicolored rocks of the Wadi Malahah and Mayza' quadrangles, where isoclinal folding and faulting are prevalent.

4. Layered rocks in the Tathlith area are generally more calcareous than those to the south. In addition to the presence of numerous thin marble lenses within the region, wide areas are underlain by calcareous mudstones and siltstones.

5. There is no great continuity of particular formations along strike. For example, great thicknesses of graphitic schists found in the Wadi Malahah quadrangle area are not found elsewhere, particularly not in the northern part of the belt in the Wadi Haraman quadrangle where only very minor graphitic zones were found. However, this may not be valid negative criteria since varied depositional conditions would be expected in a geosynclinal belt 275 km long.

6. The presence of granodiorite or tonalite pebbles in the metaconglomerate of Simmon's (1980) MV_4 formation in the Madha quadrangle implies that at least some of the metasedimentary rocks in this area were formed later than at least one stage in the formation of the Wadi Tarib batholith.

Geochronological dating of rocks appears to lack accuracy, especially in the southern part of the Tathlith-Kutam belt of rocks, and ages given for layered rocks in the Jabal al Qarah quadrangle are termed tentative by Schmidt (in press). More samples have been collected for age dating using the zircon method and hopefully will closely define the ages of the layered rocks within the belt.

Some of the evidence cited above suggests a younger age, by as much as 100 m.y., for layered rocks of the Tathlith region. Such an age difference could be explained by large-scale faulting and displacement or large-scale downwarping, and there is no evidence for either of these phenomena. The Tathlith-Kutam belt of layered rocks appears to be normally positioned and fits the model for incremental growth of a craton in an easterly direction. Locally, some of the metasedimentary rocks in the north do appear more mature and of a terrigenous nature. But these are broadly flexured, relatively flat-lying formations in contrast to other layered rocks of the area and there is some evidence that they unconformably overlie other layered rocks.

False-color Landsat images show the presence of layered rocks of the Tathlith-Kutam belt over most of its length. In most of the images, layered rocks may be clearly distinguished from intrusive rocks and covered areas are easily delineated. All of the various color combinations display images which are similar to the units in plate 1, especially in the Markas quadrangle area, where many of the small isolated outcrops of metasedimentary rocks, underlain by large areas of intrusive rocks (Warden, unpub. data), are faithfully reproduced. This indicates to the author that only the long strand of layered rocks which crosses the eastern part of the Madha quadrangle area has survived batholithic intrusion and that xenolithic fragments of layered rocks found in the Markas quadrangle were once part of a continuous belt at least 50 km wide. A large part of the Tathlith one-degree quadrangle area shows similar characteristics.

The Landsat images also clearly show major faulting across the belt of layered rocks; especially prominant is the major Najd-type fault zone which crosses the northern part of the Markas quadrangle area in a west-northwesterly direction. This fault zone appears to terminate against the Jabal Ishmas-Wadi Tathlith fault zone where layered rocks form an unbroken north-trending belt and do not appear to have undergone lateral displacement.

In summation, it is believed that layered rocks in the Tathlith-Kutam belt follow a normal stratigraphic succession and that there are no major breaks in stratigraphic continuity. The evidence presented suggests that layered rocks in the northern part of the region have undergone more evolution than their southern counterparts; if this is so, age differences are not great and age differences of as much as 100 m.y., as taken from geochronological studies, do not appear to be valid.

ECONOMIC GEOLOGY OF PREVIOUSLY UNREPORTED MINERAL OCCURRENCES IN THE TATHLITH AREA

Discussion

This report will treat only those mineral deposits not reported by previous authors and will briefly describe pyritized and gossanized zones and a few ancient gold mines. Names of the deposits were not obtained.

Several zones in the Al Hassir and Duthur as Salam quadrangles display disseminated pyrite or pyrrhotite. These fresh sulfides are ordinarily found in silicified basalts or andesites and no evidence of other sulfide minerals was found. The following are atomic absorption and colorimetric assay results.

Sample number	Coordinates	Au (grams per ton)	Ag (grams per ton)	Cu (parts per million)	Pb (parts per million)	Zn (parts per million)	Ni (parts per million)	Mo (parts per million)
130344	19°46'15"N. 43°18'55"E.	nil	1.0	80	15	5	80	nil
130361	19°41'00"N. 43°23'55"E.	nil	<0.5	5	20	30	15	nil
130371	19°22'30"N. 43°20'50"E.	nil	<0.5	5	10	20	15	nil
130376	19°44'40"N. 43°20'05"E.	nil	<0.5	10	40	65	10	nil
130377	19°12'05"N. 43°23'50"E.	nil	1.0	55	20	40	20	nil
130380	19°07'00"N. 43°21'20"E.	nil	1.0	10	20	35	85	nil
130384	19°04'00"N. 43°21'50"E.	nil	1.0	10	20	85	25	nil

Additional semi-quantitative spectrographic analyses for 23 other elements revealed no anomalous values and from the above results it is concluded that these particular disseminated sulfide zones bear no economic significance.

Several previously unreported ancient gold mines were located and dump samples were obtained. All of the workings are on milky quartz veins or on selvages and none display other types of mineralization.

Analysis of three grab samples from dumps at an ancient working located at lat 19°49'40"N., long 43°20'25"E. (number 1, pl. 1) gave the following results.

Sample number	Au	Ag
	grams per ton	
130295	0.36	5.0
130296	0.10	<0.5
130297	0.18	1.0

The workings consist of intermittent trenches along a lenticular quartz vein trending north along a brecciated, silicified, and pyritized contact of metasedimentary rocks with diorite. The line of trenches is about 200 m long and the vein is over 2 m wide in places.

A quartz vein in diorite at lat 19°51'35"N., long 43°17'03"E. (number 2, pl. 1) was pitted by the ancients. Two shallow workings on the vein disclose rusty quartz veining in faulted diorite. One grab sample from dumps was assayed as follows.

Sample number	Au	Ag
	grams per ton	
130302	0.10	<0.5

At lat 19°47'45"N., long 43°30'10"E. (number 3, pl. 1) a system of quartz veins crops out intermittently for a distance of 2.3 km. Trenches and underground workings indicate a moderate amount of exploitation by the ancients. The quartz veins, which probably average less than a meter in thickness, appear to be fissure fillings in a strand of the Jabal Ishmas-Wadi Tathlith fault system. They are hosted by argillites and calcareous siltstones, contain limonite after pyrite, and in places dip flatly to the east. Dumps were cursorily grab-sampled with the following results.

Sample number	Coordinates	Au grams per ton	Ag grams per ton	Remarks
130309	19°49'35"N. 43°30'50"E.	12.0	2.0	Pit about 10 m long
130310	19°47'45"N. 43°30'25"E.	0.10	1.0	Two pits 20x15 m-dip underground flatly to east
130311	19°48'20"N. 43°30'10"E.	11.0	2.0	Trench on quartz vein 70 m long,2 m wide and 1 m deep
130312	19°47'05"N. 43°30'50"E.	6.8	3.0	Vein 2 m wide, numerous pits and trenches

At lat 19°09'04"N., long 43°29'04"E. (number 4, pl. 1) a gossan 325 m long and approximately 2 m wide crops out in a moderately serpentinized complex of ultramafic and calcareous rocks. Approximately 1.5 km to the northeast is another gossanized zone; from aerial photographs it appears that the gossans are on a major northeast-trending structure. They are obviously oxidized products of leached sulfides, have a cellular texture, and contain goethite and hematite. No secondary base metal or nickel minerals were noted in outcrop. Chip samples of the gossans using atomic absorption and colorimetric methods assayed as follows.

Sample number	Ni (parts per million)	Co (parts per million)	Cr (parts per million)
130395	1000	70	840
130396	1100	80	1540

Semiquantitative spectrographic analysis of sample number 130395 indicated 2.0 grams per ton silver.

Conclusions and recommendations

Ancient gold mines in the Tathlith area require detailed mapping and sampling. Worl (1979) has completed this work at Lugatah and Avala and has done minor sampling at Jabal Houbuyet. Clusters of deposits in the Lugatah-Avala area could provide enough tonnage for a commercial operation if gold in sufficient quantity is obtained. Detailed exploration in this zone would undoubtedly reveal additional potential tonnage.

The gossans found in the area of the Duthur as Salam quadrangle at lat 19°09'04"N., long 43°29'04"E. require detailed mapping and sampling. A zone approximately 1.5 km in length located between outcropping gossans should be examined in detail and surveyed by geophysical methods. A serpentinized zone, adjacent and to the west of the gossans, is approximately 15 km long and has not been studied in any detail. The entire zone should be mapped and sampled with particular attention given to the search for nickel, chromium, and asbestos.

REFERENCES CITED

Aldrich, L.T., Brown, G.F., Hedge, Carl, and Marvin, Richard, 1978, Geochronologic data for the Arabian Shield, Sec. 1 - Radiometric age determinations of some rocks from the Arabian Shield, by L.T. Aldrich, Sec. 2 -Tabulation of Rb-Sr and K-Ar ages given by rocks of the Arabian Shield, by G.F. Brown, Carl Hedge, and Richard Marvin: U.S. Geological Survey Open-File Report 78-75, 20 p.

Anderson, R.E., 1978, Geology of the Mayza quadrangle, sheet 17/43 B, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-31, scale 1:100,000.

Cooper, J.A., Stacey, J.S., Stoeser, D.B., and Fleck, R.J., 1979, An evaluation of the Zircon method of isotopic dating in the southern Arabian Craton, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 79-1187, 32 p.

Fleck, R. J., Greenwood, W. R., Hadley, D. G., Anderson, R. E., and Schmidt, D. L., 1979, Age and evolution of the southern part of the Arabian Shield, p. 1-17; in Al Shanti, A. M., Evolution and mineralization of the Arabian-Nubian Shield: Oxford, Pergamon Press, v. 3, 164 p.

Fleck, R. J., Greenwood, W. R., Handley, D. G., Anderson, R. E. and Schmidt, D. L., 1980, Rubidium-strontium geochronology and plate tectonic evolution of the southern part of the Arabian Shield: U.S. Geological Survey Professional Paper 1131, 38 p.

Greenwood, W.R., 1980a, Reconnaissance geology of the Wadi Malahah quadrangle, sheet 18/43 D, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-39, 38 p., scale 1:100,000.

Greenwood, W.R., 1980b, Reconnaissance geology of the Wadi Wassat quadrangle, sheet 18/44 C, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-40, 52 p., scale 1:100,000.

Greenwood, W.R., Anderson, R.E., Fleck, R.J., and Roberts, R.J., 1980, Precambrian geologic history and plate tectonic evaluation of the Arabian Shield, Directorate General of Mineral Resources, Mineral Resources Bulletin 24, 35 p.

Hadley, D.G., and Schmidt, D.L., 1979, Proterozoic sedimentary rocks and basins of the Arabian Shield and their evolution: U.S. Geological Survey Open-File Report 79-1189, 41 p.

Helaby, A.M., and Worl, R.J. 1981, Exploration and evaluation of the Hajrah-Hamdah group of ancient gold mines, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 81-445, 57 p.

Overstreet, W.C., 1978, A geological and geochemical reconnaissance of the Tathlith one-degree quadrangle, sheet 19/43, Kingdom of Saudi Arabia: U. S. Geological Survey Open-File Report 78-1072, 4 pls.

Riofinex Geological Mission, 1978, An investigation of the geology and exploration potential of the Wadi Wassat-Kutam district, southeast Asir, Saudi Arabia: Riofinex Geological Mission (Saudi Arabian Report RF-1978-3, 129 p.

Rooney, L.F., and Al-Koulak, Ziad, 1979, Asbestos occurrences in serpentinites of the Hamdah area, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 79-360, 22 p.

Rye, R.O., Roberts, R.J., Whelan, J.F., and Mawad, M.M., in press, Reconnaissance sulfur isotope investigations of mineral deposits in the Precambrian Shield, Kingdom of Saudi Arabia: Economic Geology.

Schaffner, D.F., 1956a, Avala mine assays: Saudi Arabian Mining Syndicate Records, unnumbered, available at Directorate General of Mineral Resources Technical Library, 1 p.

Schaffner, D.F., 1956b, Al Lugatah assays: Saudi Arabian Mining Syndicate Records, unnumbered, available at Directorate General of Mineral Resources Technical Library, 1 p.

Schaffner, D.F., 1964, Ancient mines and mineral occurrences, quadrangle 217: Saudi Arabian Directorate General of Mineral Resources Miscellaneous Record DGMR-222, 2 p.

Schmidt, D.L., in press, Geology of the Jabal al Qarah quadrangle, sheet 20/43 C, Kingdom of Saudi Arabia: Saudi Arabia Directorate General of Mineral Resources Geologic Map.

Schmidt, D.L., Hadley, D.G., and Stoeser, D.B., 1978, Late Proterozoic crustal history of the Arabian Shield, southern Najd Province, Kingdom of Saudi Arabia: King Abdulaziz University Institute of Applied Geology Symposium on the Evolution and mineralization of the Arabian-Nubian Shield, Jiddah Feb. 1978, Bull. 3, v. 2, p. 41-58.

Simmons, G.C., 1980, Reconnaissance geology of the Madha quadrangle, sheet 18/43 A, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 80-133, 40 p., 2 pls, scale-1:100,000.

Smith, C.W., 1979, Ancient mines of the Farah Garan area, southwestern Saudi Arabia, with a section on Reconnaissance geophysical exploration by H.R. Blank: U.S. Geological Survey Open-File Report 79-1659, 56 p., 7 pls.

Smith, C.W., 1981, Mineral deposits of the Dhahar-Al Hajrah region, southwestern Saudi Arabia, with a note on the ancient mine at Shasrah: U.S. Geological Survey Open-File Report 81-561, 35 p.

Smith, C.W., Anderson, R.E., and Dehlavi, M.R., 1978, Geology and Ore deposits of the Kutam mine, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 78-519, 51 p., 2 pls.

Stacey, J.S., Delevaux, M.H., Gramlich, J.W., Doe, B.R., and Roberts, R.J., 1981, A lead isotope study of mineralization in the Arabian Shield: U.S. Geological Survey Open-File Report 81-193, 30 p.

Worl, R. G., 1980, Gold deposits associated with the Jabal Ishmas-Wadi Tathlith fault zone, in Evolution and mineralization of the Arabian Nubian Shield: King Abdulaziz University, Faculty of Earth Sciences, I.A.G. Bull. no. 3, New York, Pergamon Press, v. 4, p. 61-69.

Worl, R.J., 1979, The Jabal Ishmas-Wadi Tathlith gold belt, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 79-1519, 108 p., 4 pls.

Worl, R.G., 1981, , Reconnaissance geology of the Jabal al Hajrah 7-1/2 minute quadrangle, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 81-1218, 31 p.

Worl, R.J., and Elsass, F.E., 1981, Evaluation of mineralization in serpentinite and enclosing rocks in the Hamdah area, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 81-446, 38 p.